Modeling Approaches for Understanding and Predicting Soil Carbon Sequestration: Field to Landscape to Region

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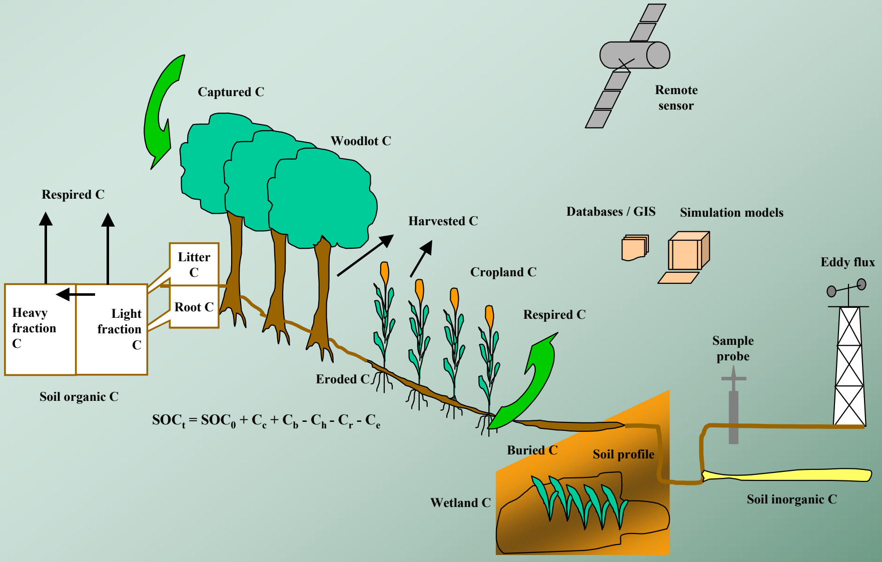
Background

- Soil carbon sequestration (SCS) has significant potential to attenuate the increase of atmospheric CO_2
  - Global: 0.4 – 0.8 Pg C y^{-1}; 50 – 100 y (IPCC 1996)
  - USA: 0.08 – 0.21 Pg C y^{-1}; 30 y (Lal et al. 1999)
- Near-term SCS potential in croplands
  - Global: 0.12 Pg C y^{-1} by 2010; 0.26 Pg C y^{-1} by 2040 (Sampson et al. 2000)
- Current estimates of SCS
  - USA: 0.021 Pg C y^{-1} during 1982 – 1997 (Eve et al. 2001)
- The deployment of SCS practices will require robust methods for monitoring soil carbon changes
- Simulation models with ability to simulate soil carbon and nitrogen dynamics can play major role in monitoring SCS at field, landscape and regional scales

Detecting and scaling changes in soil carbon

- Detecting soil C changes
  - Difficult on short time scales
  - Amount changing small compared to total C
- Methods for detecting and projecting soil C changes (Post et al. 2001)
  - Direct methods
    - Field and laboratory measurements
    - Eddy covariance
  - Indirect methods
    - Accounting
      - Stratified accounting
    - Remote sensing
    - Models

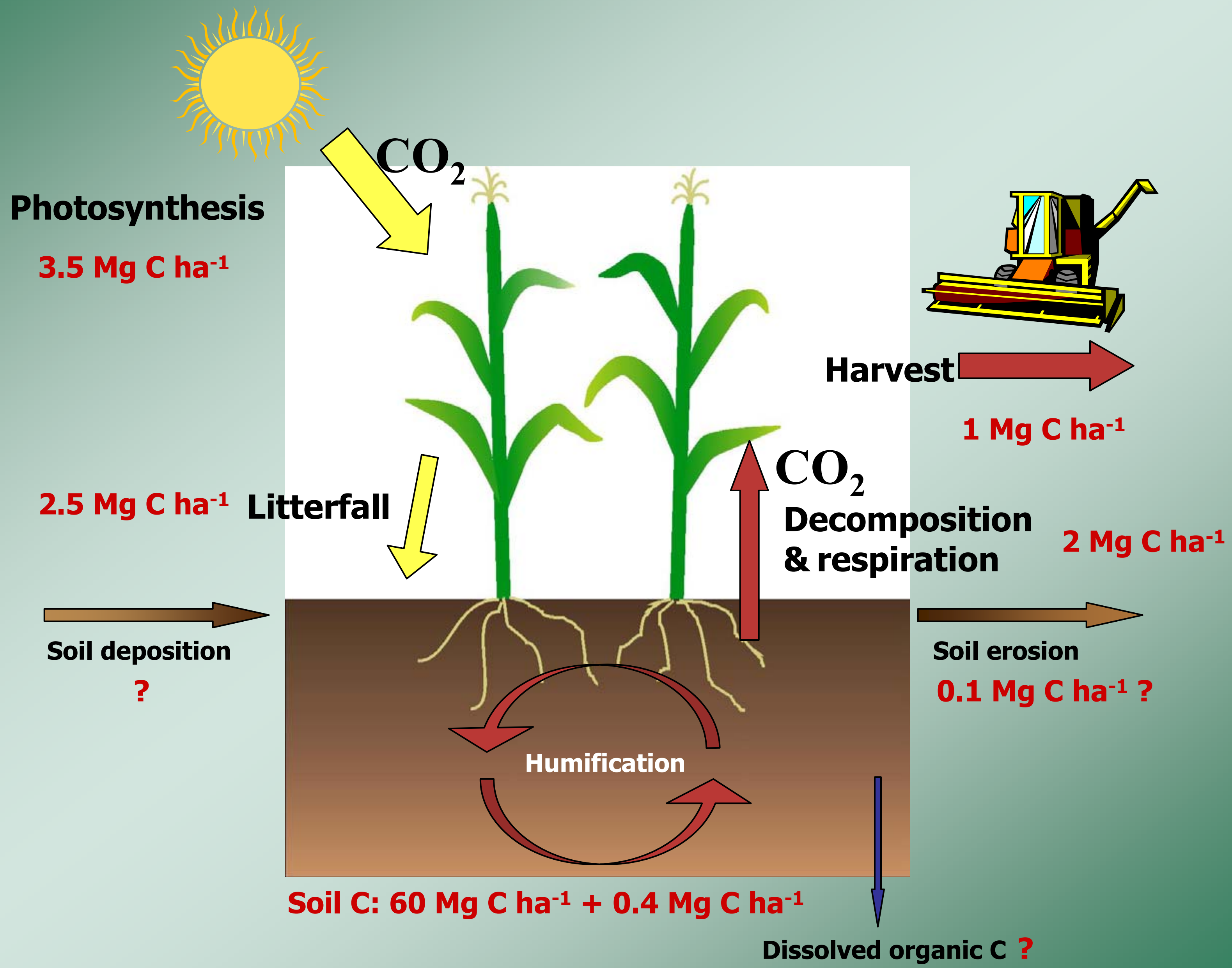


Post et al. (2001)

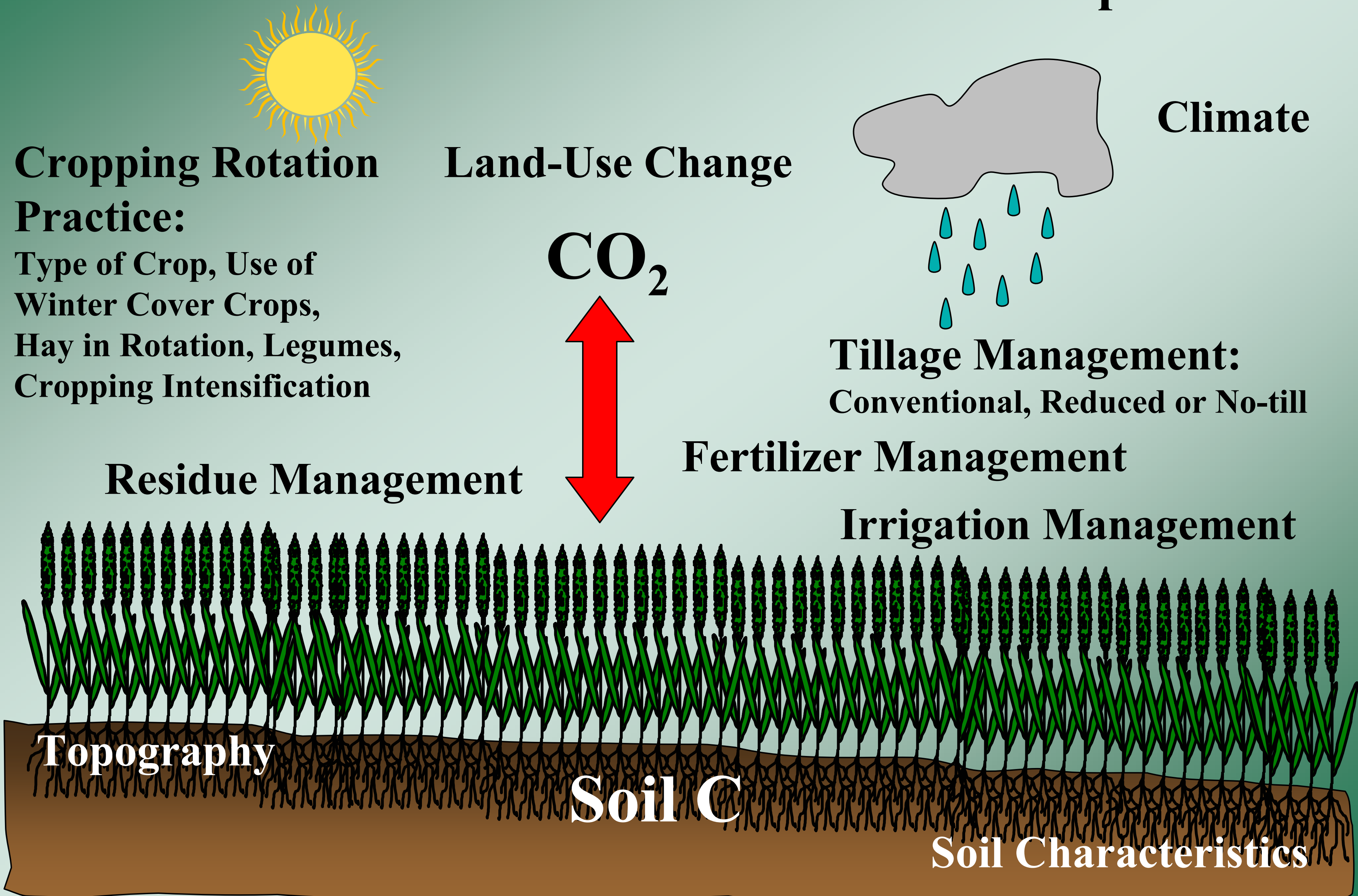
Objectives

- Review components and drivers of the carbon balance in agroecosystems
- Discuss modeling approaches in Century and EPIC
- Present examples of applications of these models at various scales of spatial resolution
  - Field
  - Landscape
  - Region

Annual Carbon Balance in an Agroecosystem



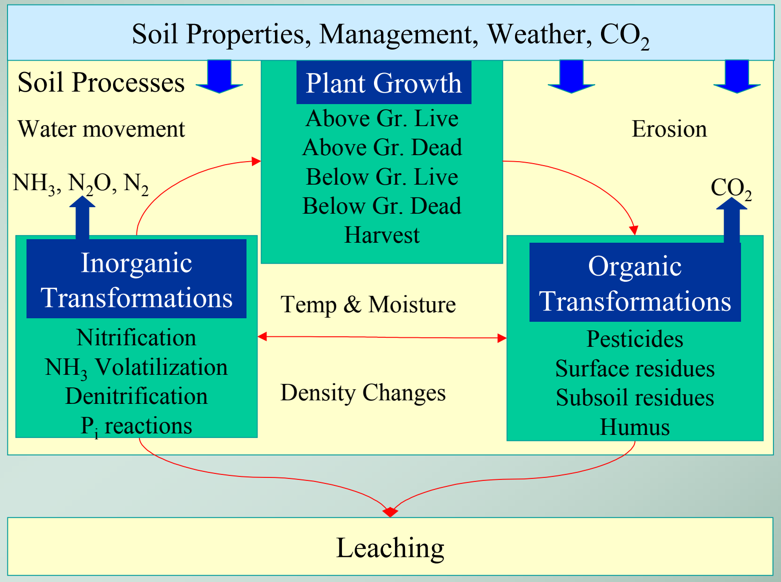
Environmental Variables and Management Determine Carbon Flux Between Soils and the Atmosphere



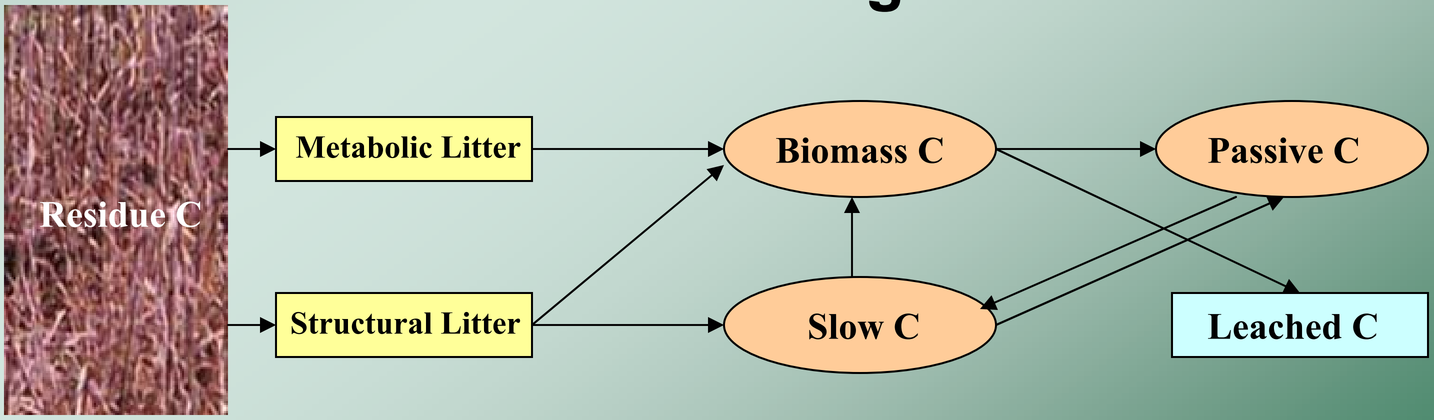
Two terrestrial ecosystem models

- Century
  - Century
  - DayCent
  - C-STORE
- EPIC
  - EPIC
  - APEX

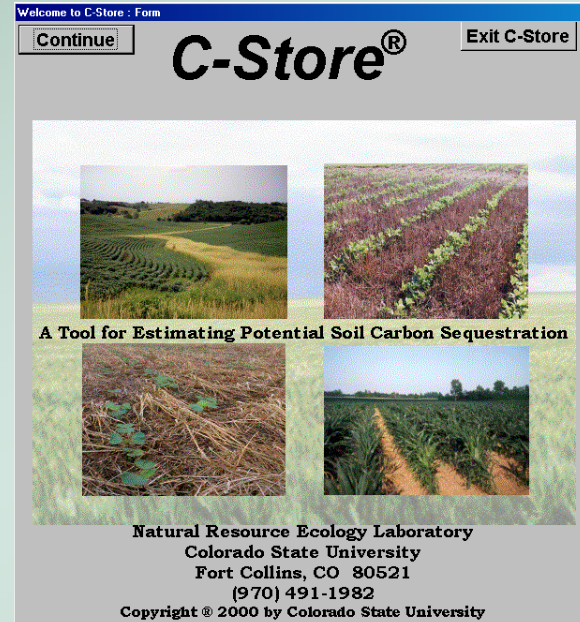
Processes and drivers

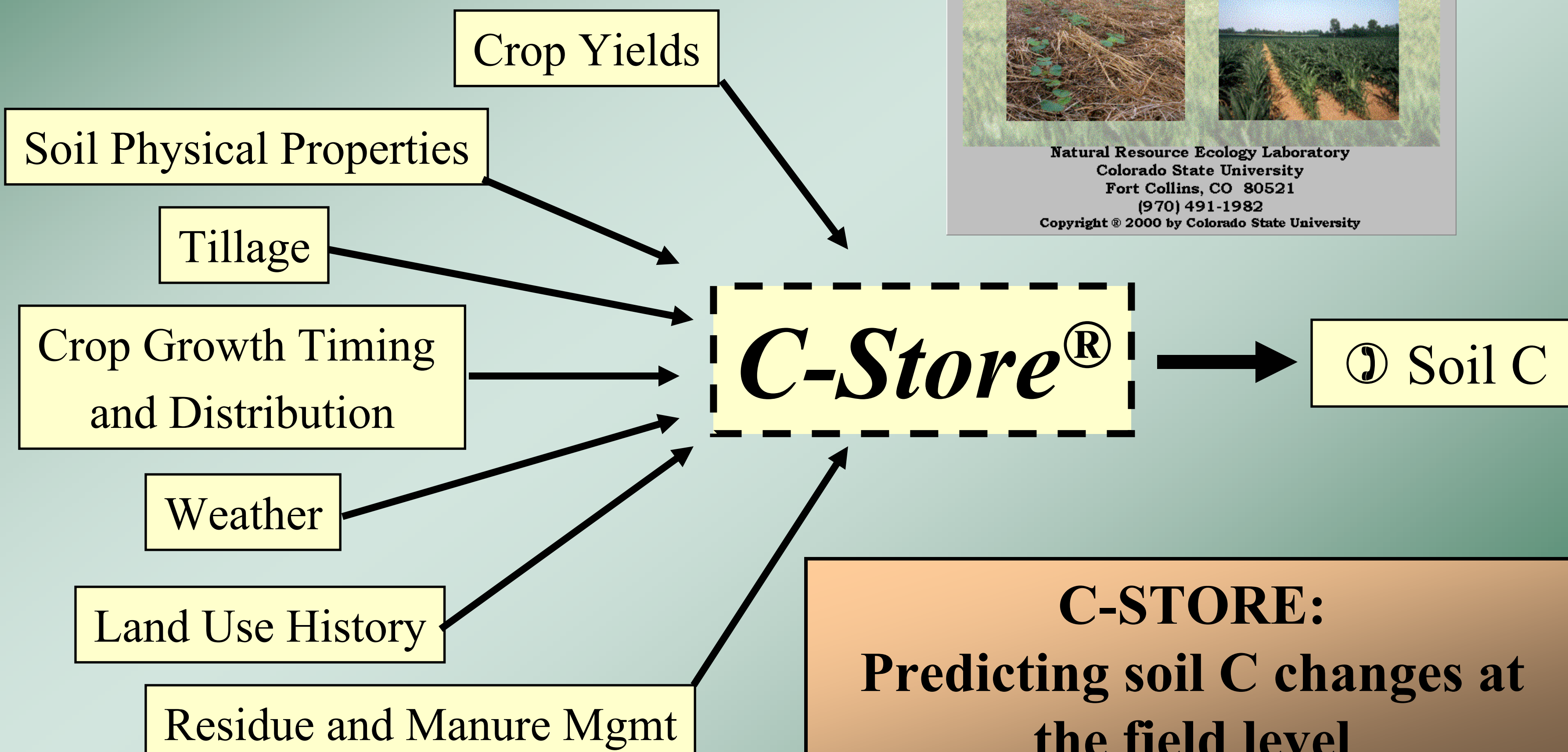


Carbon and nitrogen flows

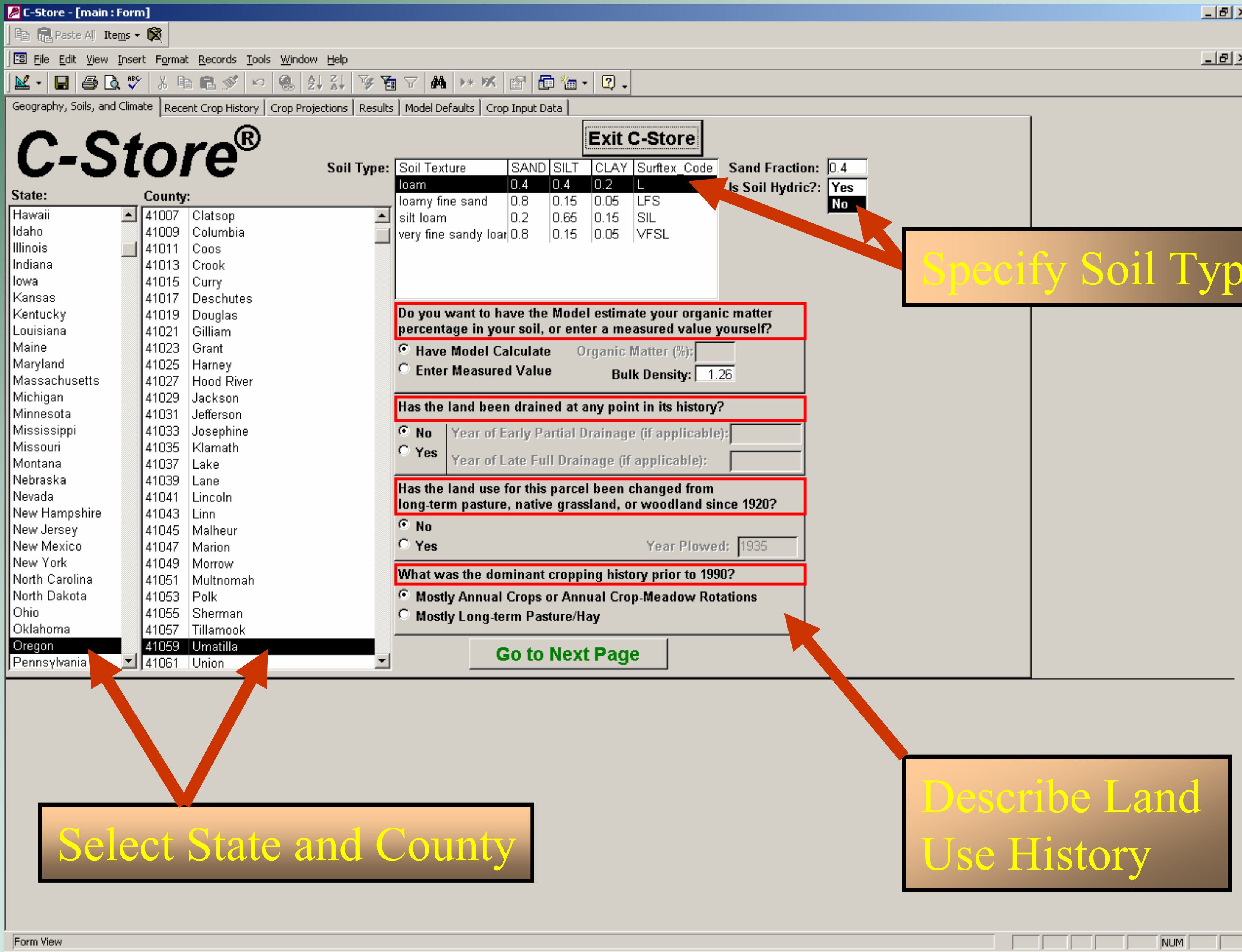


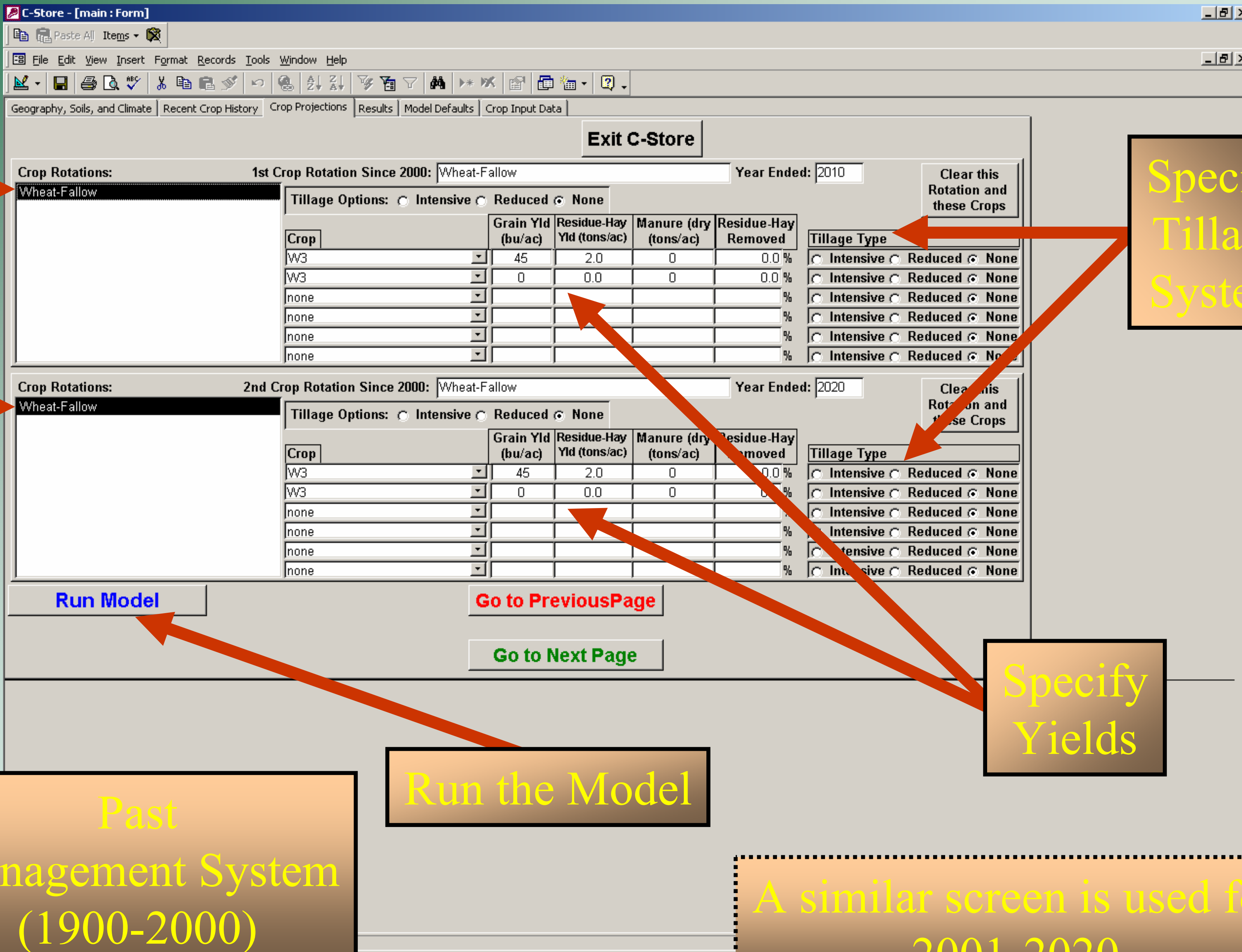
The *C-Store*® Soil Carbon Model





C-STORE:
Predicting soil C changes at the field level


C-Store - [main : Form]
Geography, Soils, and Climate
Recent Crop History
Crop Projections
Results
Model Defaults
Crop Input Data
C-Store®
Exit C-Store
Soil Type:
Soil Texture | SAND | SILT | CLAY | Surftex_Code
loam | 0.4 | 0.4 | 0.2 | L
loamy fine sand | 0.8 | 0.15 | 0.05 | LFS
silt loam | 0.2 | 0.65 | 0.15 | SIL
very fine sandy loar | 0.8 | 0.15 | 0.05 | VFSL
Sand Fraction: 0.4
Is Soil Hydric?: Yes No
State:
County:
Oregon
41059 Umatilla
Do you want to have the Model estimate your organic matter percentage in your soil, or enter a measured value yourself?
Have Model Calculate
Enter Measured Value
Organic Matter (%):
Bulk Density: 1.26
Has the land been drained at any point in its history?
No
Yes
Year of Early Partial Drainage (if applicable):
Year of Late Full Drainage (if applicable):
Has the land use for this parcel been changed from long-term pasture, native grassland, or woodland since 1920?
No
Yes
Year Plowed: 1935
What was the dominant cropping history prior to 1990?
Mostly Annual Crops or Annual Crop-Meadow Rotations
Mostly Long-term Pasture/Hay
Go to Next Page
Form View
NUM
Specify Soil Type
Select State and County
Describe Land Use History



Specify Tillage System

Specify Yields

Run the Model

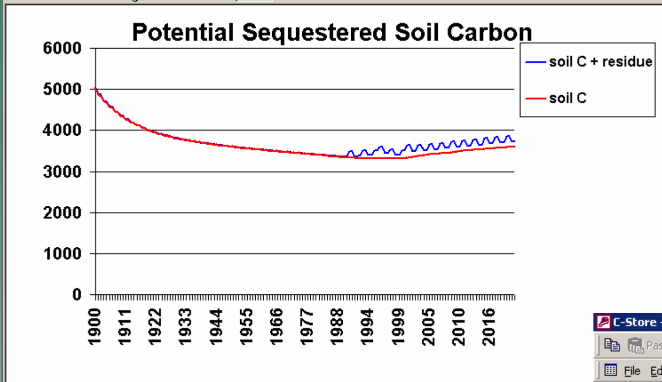
Past Management System (1900-2000)

A similar screen is used for 2001-2020

C-Store - [main : Form]

Geography, Soils, and Climate | Recent Crop History | Crop Projections | Results | Model Defaults | Crop Input Data

Refresh Graph | Beginning Year of Plot: 1900 | Ending Year of Plot: 2020 | View Data | Exit C-Store



Go to PreviousPage

Form View

Graphic output

C-Store - [results : Table]

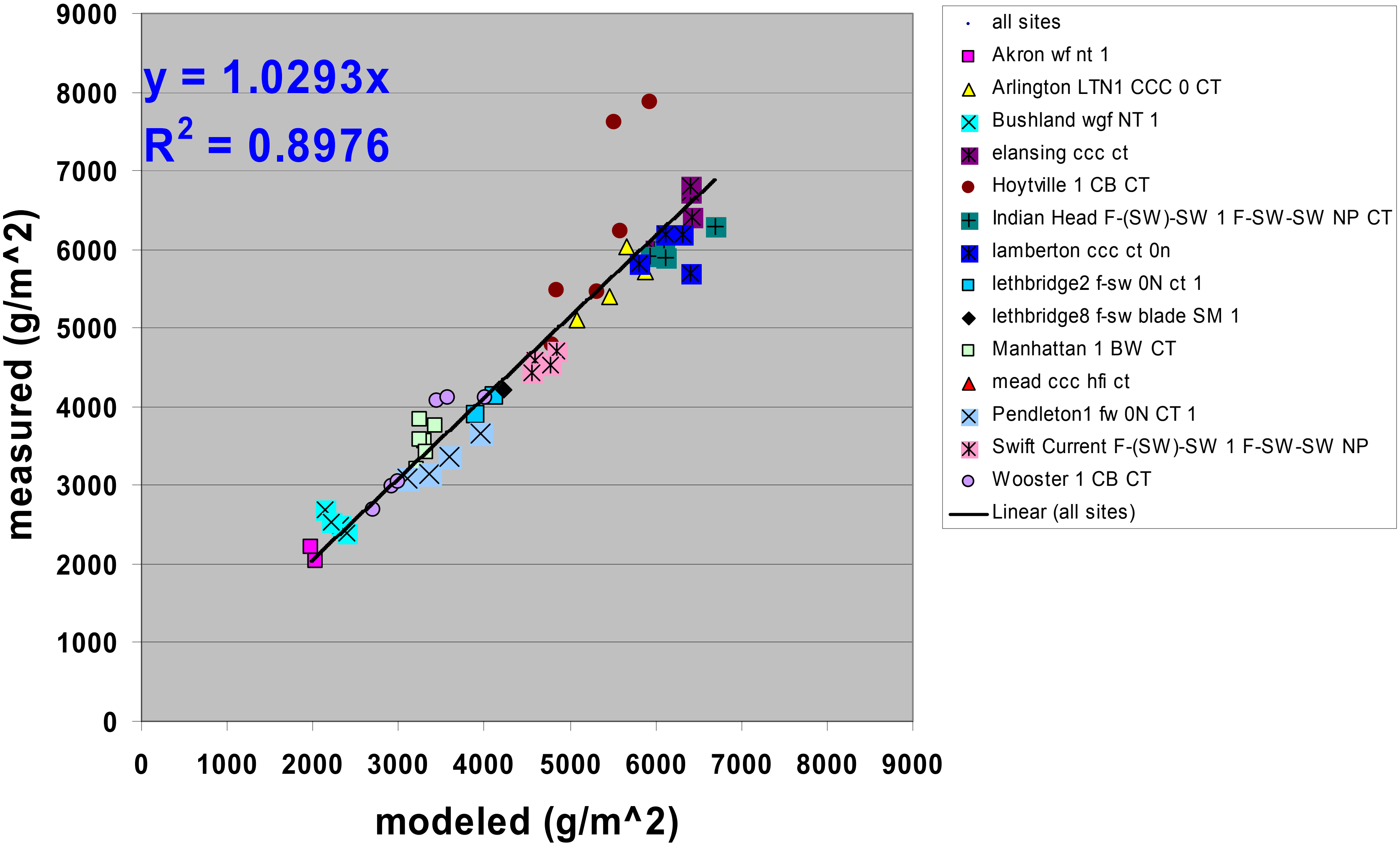
ID	yr	soilc	totalc	active	slow	passive	somtc	str1	met1	residue	totc
22075	2006	3421.04	3536.02	93.54	363.15	2964.34	3421	114	1	115	3536
22076	2007	3442.57	3692.04	98.45	382.08	2962.05	3443	236	13	249	3692
22077	2008	3451.31	3564.7	92.14	399.37	2959.8	3451	113	1	113	3565
22078	2009	3472.33	3720.81	97.87	416.91	2957.55	3472	235	13	248	3721
22079	2010	3480.44	3593.36	92.02	433.07	2955.35	3480	112	1	113	3593
22080	2011	3500.83	3749.02	98.08	449.61	2953.14	3501	235	13	248	3749
22081	2012	3508.27	3621.05	92.4	464.89	2950.98	3508	112	1	113	3621
22082	2013	3528	3776.1	98.57	480.62	2948.82	3528	235	13	248	3776
22083	2014	3534.77	3647.51	92.94	495.13	2946.7	3535	112	1	113	3648
22084	2015	3553.83	3801.91	99.14	510.12	2944.57	3554	235	13	248	3802
22085	2016	3559.94	3672.66	93.52	523.92	2942.49	3560	112	1	113	3673
22086	2017	3578.35	3826.43	99.72	538.23	2940.4	3578	235	13	248	3826
22087	2018	3583.83	3696.55	94.09	551.37	2938.36	3584	112	1	113	3697
22088	2019	3601.62	3849.69	100.28	565.03	2936.31	3602	235	13	248	3850
22089	2020	3606.49	3719.22	94.65	577.54	2934.3	3606	112	1	113	3719
22090	1991	3331.61	3480.49	50.51	290.23	2990.86	3332	138	11	149	3480
22091	1992	3317.67	3384.04	62.11	265.92	2989.63	3318	66	1	66	3384
22092	1993	3317.59	3507.1	80.04	249.25	2988.3	3318	178	11	190	3507
22093	1994	3306.18	3391.91	81.86	237.38	2986.94	3306	85	1	86	3392
22094	1995	3306.17	3507.63	91.44	229.22	2985.51	3306	190	11	201	3508
22095	1996	3321.11	3588.18	108.72	228.3	2984.09	3321	255	12	267	3588
22096	1997	3316.61	3439.08	106.98	226.91	2982.71	3317	122	1	122	3439
22097	1998	3316.12	3540.24	108.24	226.57	2981.3	3316	213	11	224	3540
22098	1999	3305.09	3407.33	100.88	224.3	2979.9	3305	102	1	102	3407
22099	2000	3303.66	3515.32	102.84	222.35	2978.46	3304	201	11	212	3515
22100	2001	3339.7	3643.07	112.66	251.01	2976.03	3340	289	14	303	3643
22101	2002	3355.89	3494.74	105.82	276.41	2973.66	3356	138	1	139	3495
22102	2003	3379.19	3643.37	106.58	301.33	2971.29	3379	251	13	264	3643
[illegible]	2004	3389.73	3510.14	97.74	323.02	2968.96	3390	120	1	120	3510
22104	2005	3411.69	3664.5	100.87	344.19	2966.63	3412	240	13	253	3664
22105	2006	3421.04	3536.02	93.54	363.15	2964.34	3421	114	1	115	3536
22106	2007	3442.57	3692.04	98.45	382.08	2962.05	3443	236	13	249	3692
22107	2008	3451.31	3564.7	92.14	399.37	2959.8	3451	113	1	113	3565
22108	2009	3472.33	3720.81	97.87	416.91	2957.55	3472	235	13	248	3721
22109	2010	3480.44	3593.36	92.02	433.07	2955.35	3480	112	1	113	3593
22110	2011	3500.83	3749.02	98.08	449.61	2953.14	3501	235	13	248	3749
22111	2012	3508.27	3621.05	92.4	464.89	2950.98	3508	112	1	113	3621
22112	2013	3528	3776.1	98.57	480.62	2948.82	3528	235	13	248	3776
22113	2014	3534.77	3647.51	92.94	495.13	2946.7	3535	112	1	113	3648
22114	2015	3553.83	3801.91	99.14	510.12	2944.57	3554	235	13	248	3802
22115	2016	3559.94	3672.66	93.52	523.92	2942.49	3560	112	1	113	3673
22116	2017	3578.35	3826.43	99.72	538.23	2940.4	3578	235	13	248	3826
22117	2018	3583.83	3696.55	94.09	551.37	2938.36	3584	112	1	113	3697
22118	2019	3601.62	3849.69	100.28	565.03	2936.31	3602	235	13	248	3850
22119	2020	3606.49	3719.22	94.65	577.54	2934.3	3606	112	1	113	3719
(AutoNumber)		0	0	0	0	0	0	0	0	0	0

Record: 1 of 173

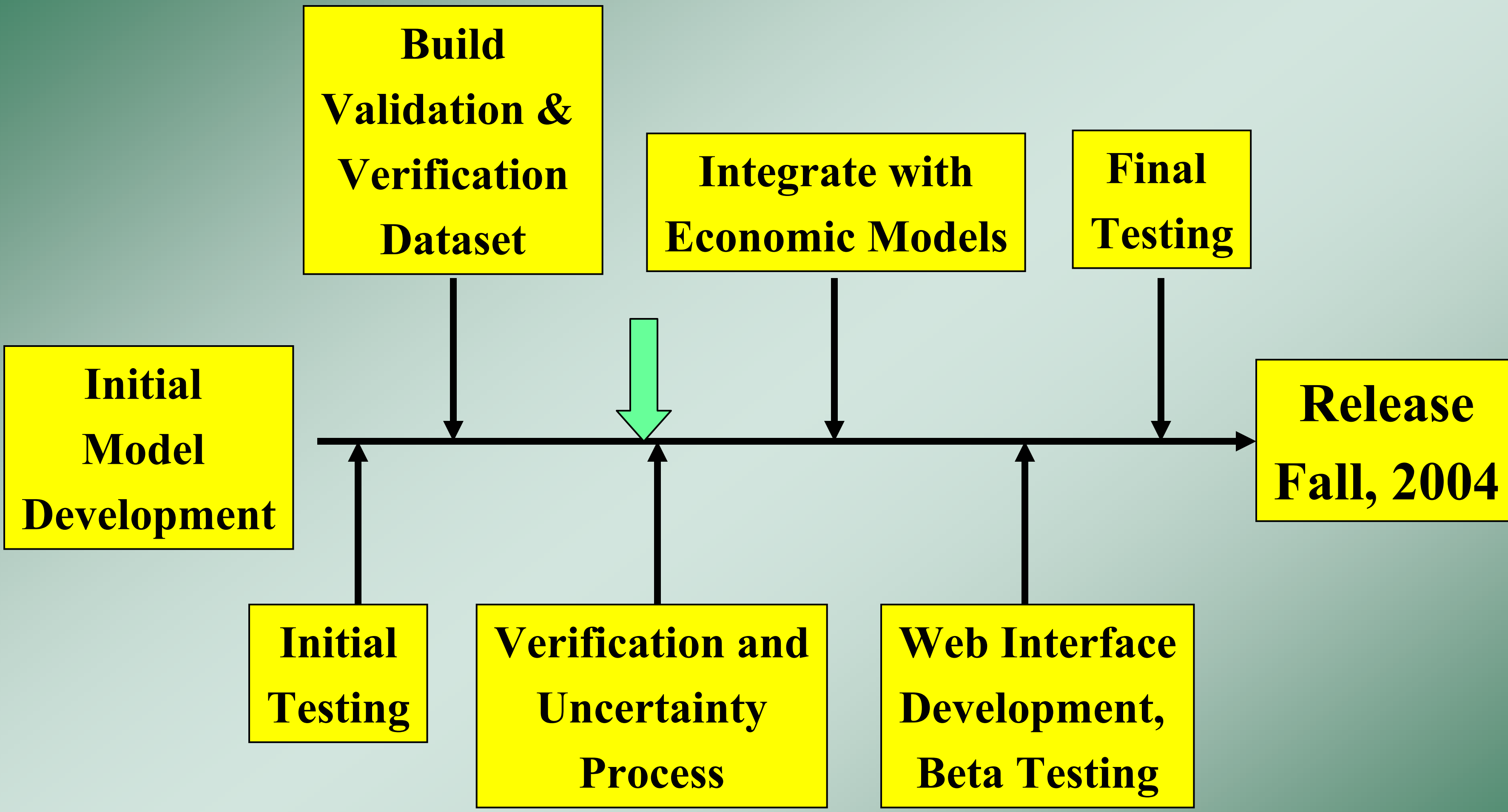
Datasheet View

Detailed tabular output

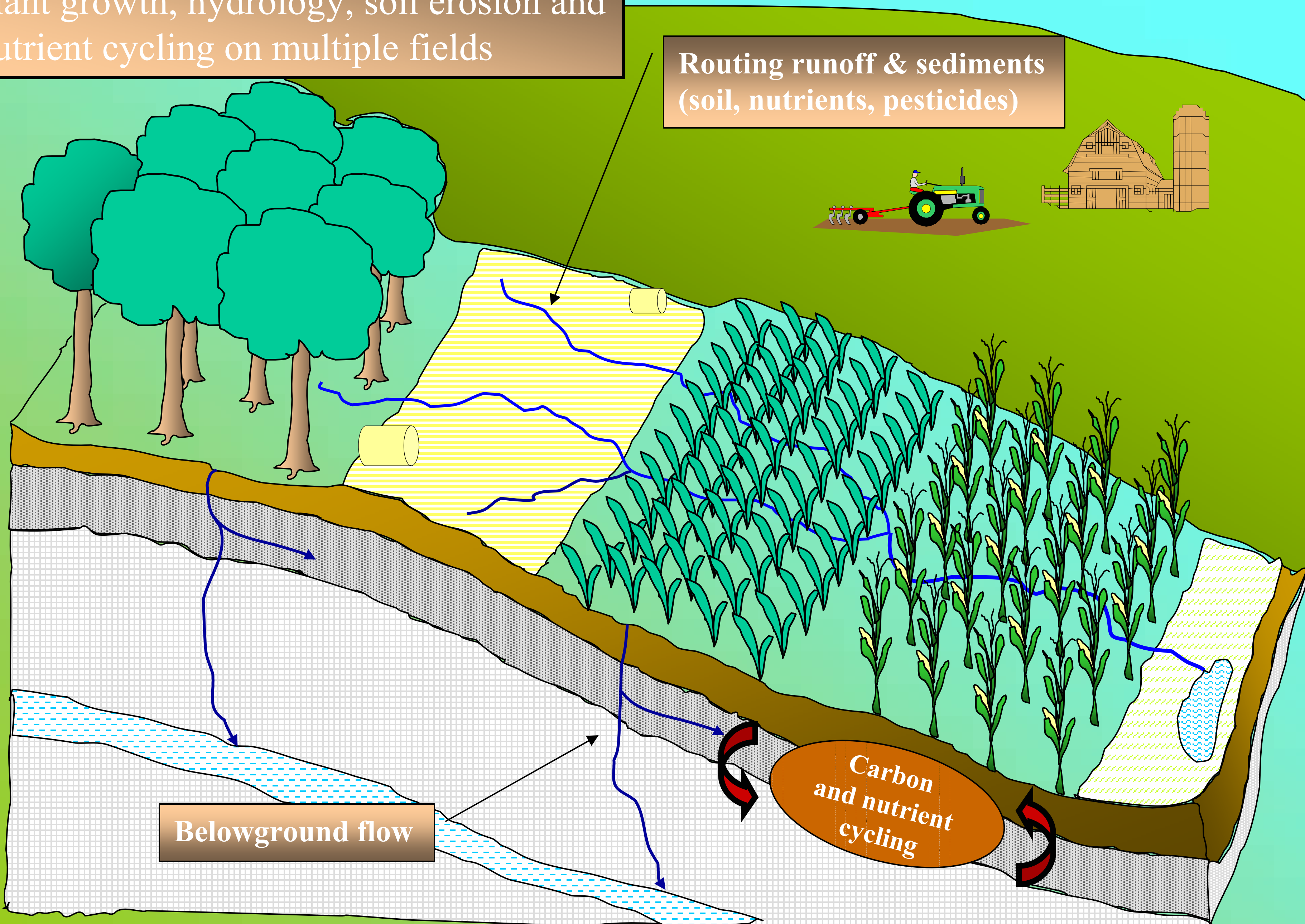
Measured vs. Modeled Soil Carbon Stocks
Measured Initial C Values



C-Store® Development Status

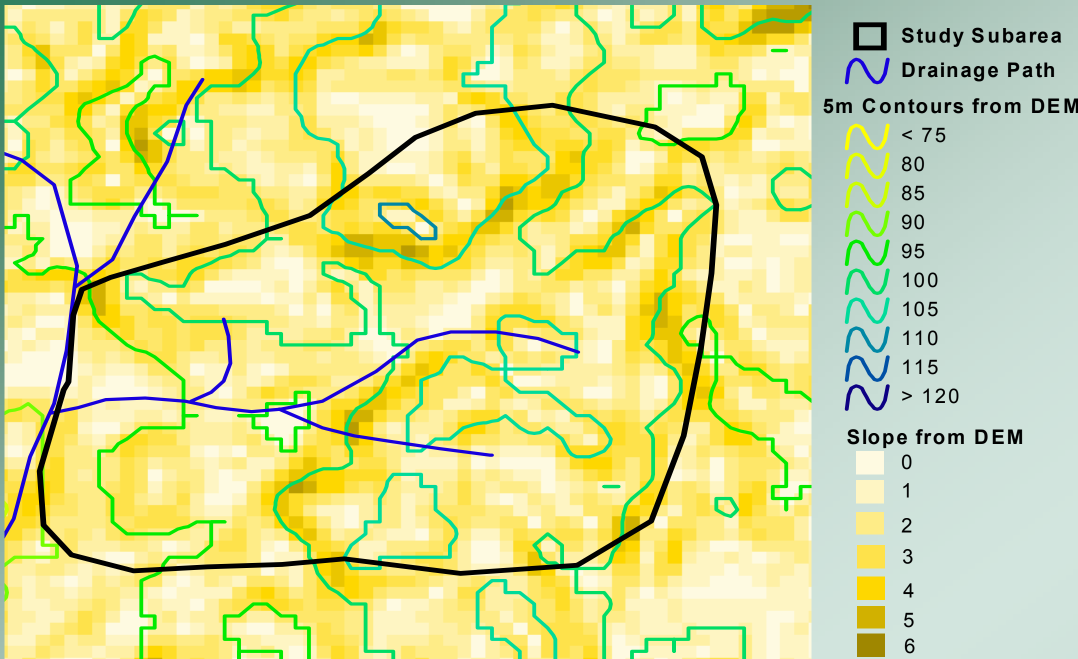


APEX, a watershed model to simulate plant growth, hydrology, soil erosion and nutrient cycling on multiple fields

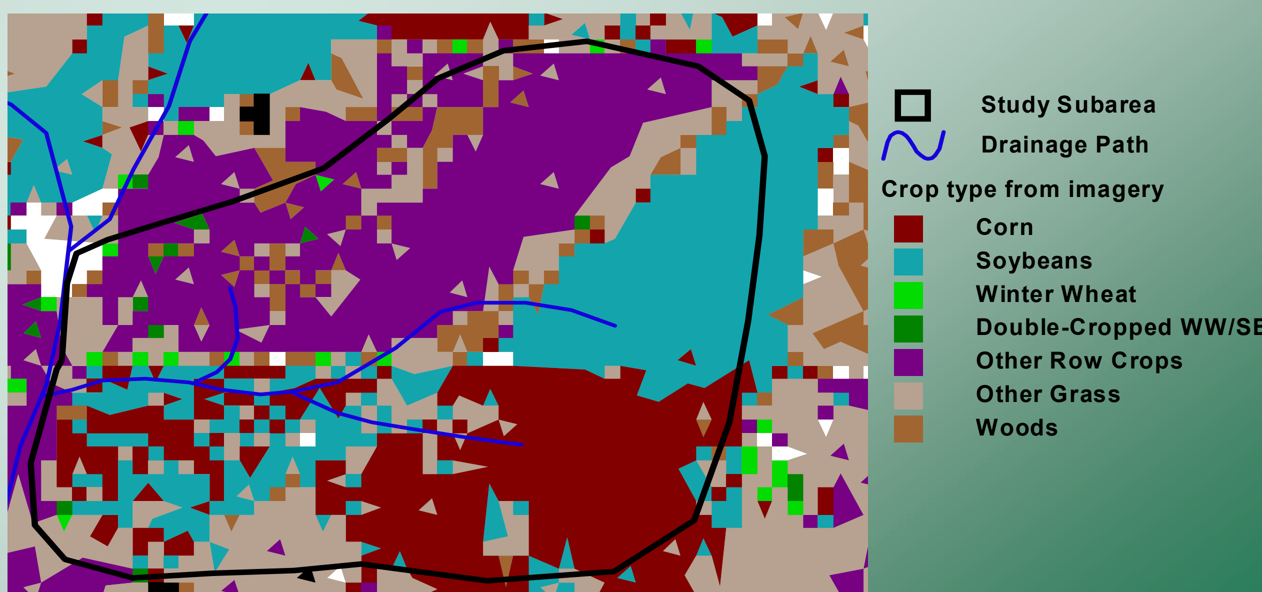


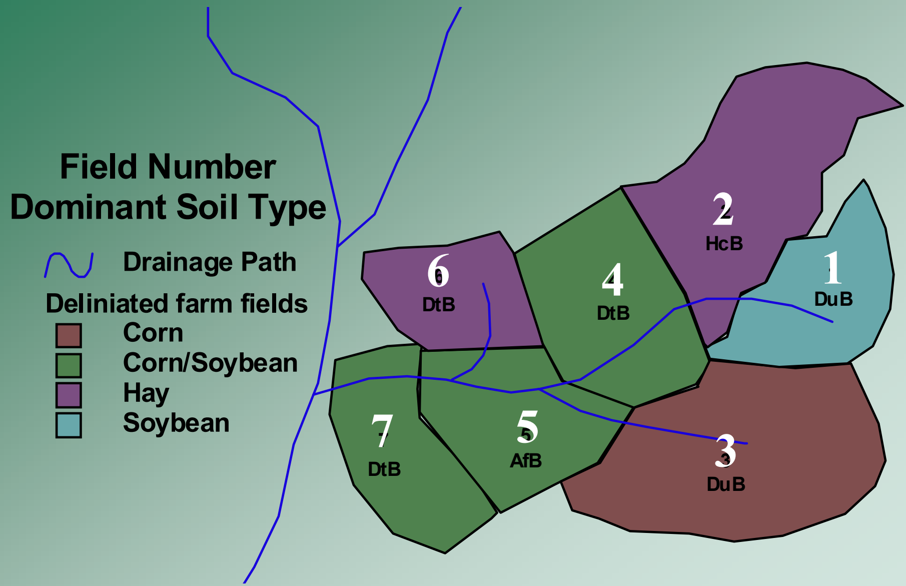
Seven fields on a hillslope in Frederick Co., MD

Digital Elevation Model help delineate drainage area



Remote Sensing imagery helps determine crop types and management





Landscape modeling is helping our understanding of the role of erosion in the carbon cycle

Routing and deposition of sediments and carbon

Tributary	Main Channel	Tributary
	Field Routing Number	
	1	
	2	
	4	
3	5	6
	7	
	Deposition of sediment (tons/ha)	
	1.26	

	0.94	
4.91	-----	0.15

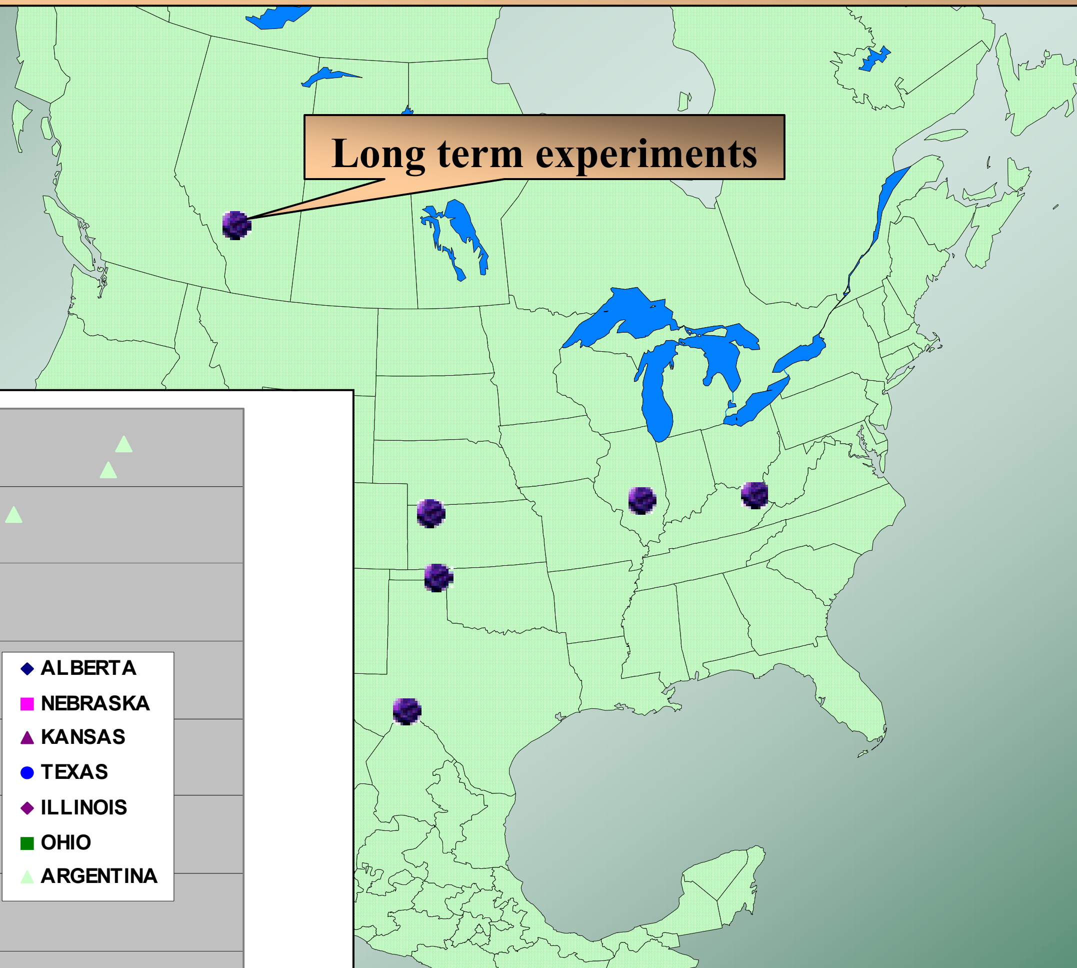
	Deposition of carbon (tons/ha)	
	0.104	

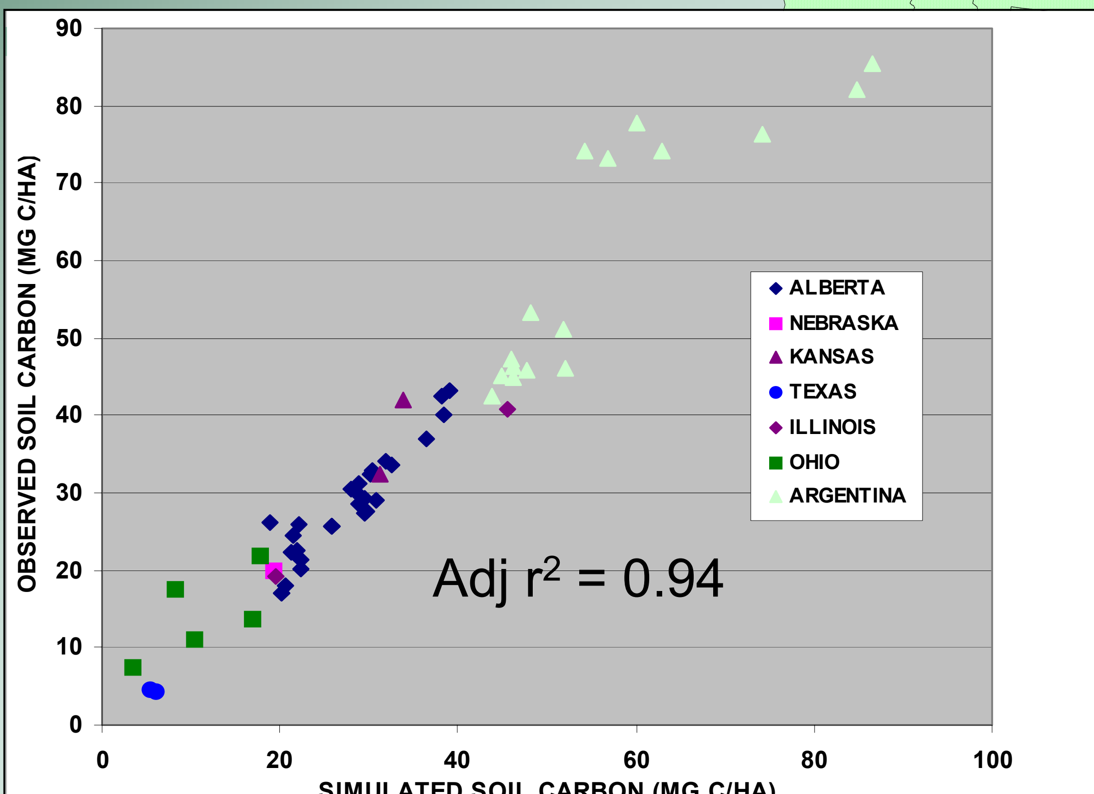
	0.070	
0.345	-----	0.012

Runoff, sediments, nutrients and soil C changes

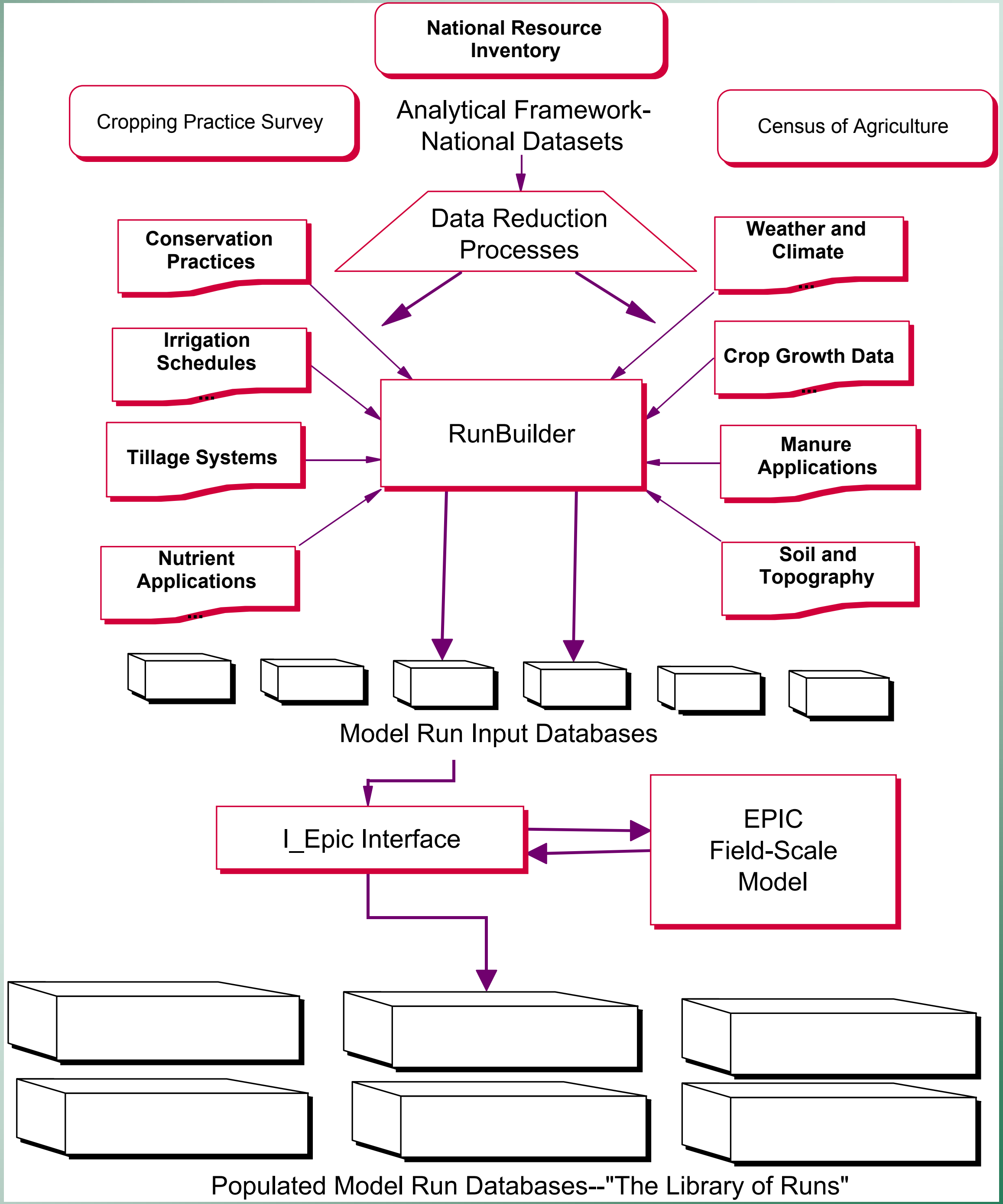
Subarea	Runoff (Q)	Sediment in Q	Soluble Nutrients in Q		Nutrient loss in sediment		Soil C Change	
			P	N	P	N	Top 0.25m	Profile
	mm	*t/ha*	----------------------------	*kg/ha*	--------------------------		-------------*t/ha*	-------------
1	164	2.1	1.4	6.2	1.5	10.5	-1.8	7.5
2	61	5.5	1.1	1.5	5.3	12.3	-6.3	1.1
3	162	4.1	1.6	2.3	2.2	7.4	-2.3	8.5
4	129	3.0	0.9	3.6	1.4	12.2	3.0	19.5
5	129	2.2	2.1	2.0	1.8	8.4	7.5	7.4
6	58	2.8	1.1	5.5	2.8	7.5	-3.7	10.1
7	126	1.5	0.9	3.3	0.8	7.3	3.2	18.9

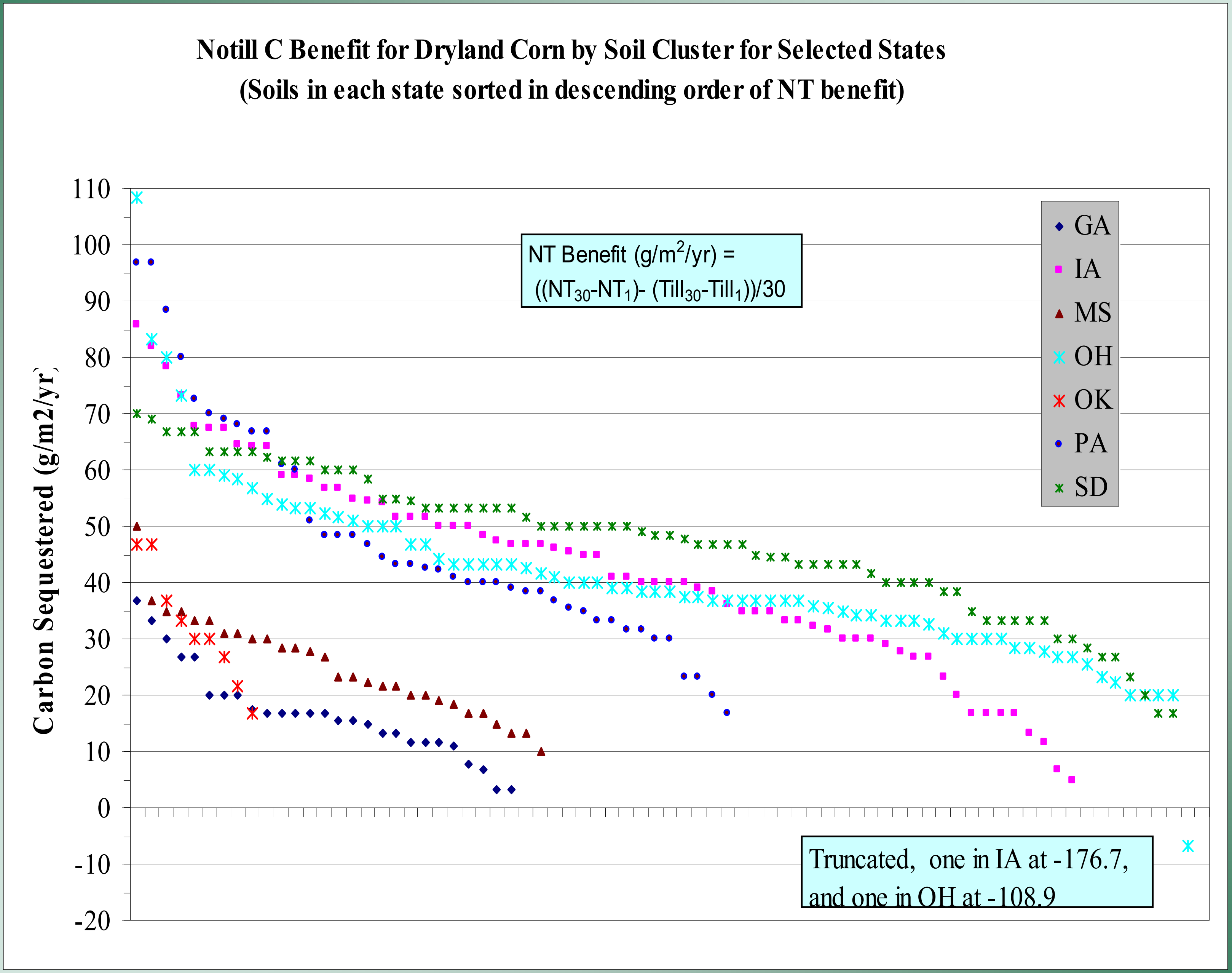
The EPIC model: validation and application to estimate soil carbon sequestration under no till at the national scale

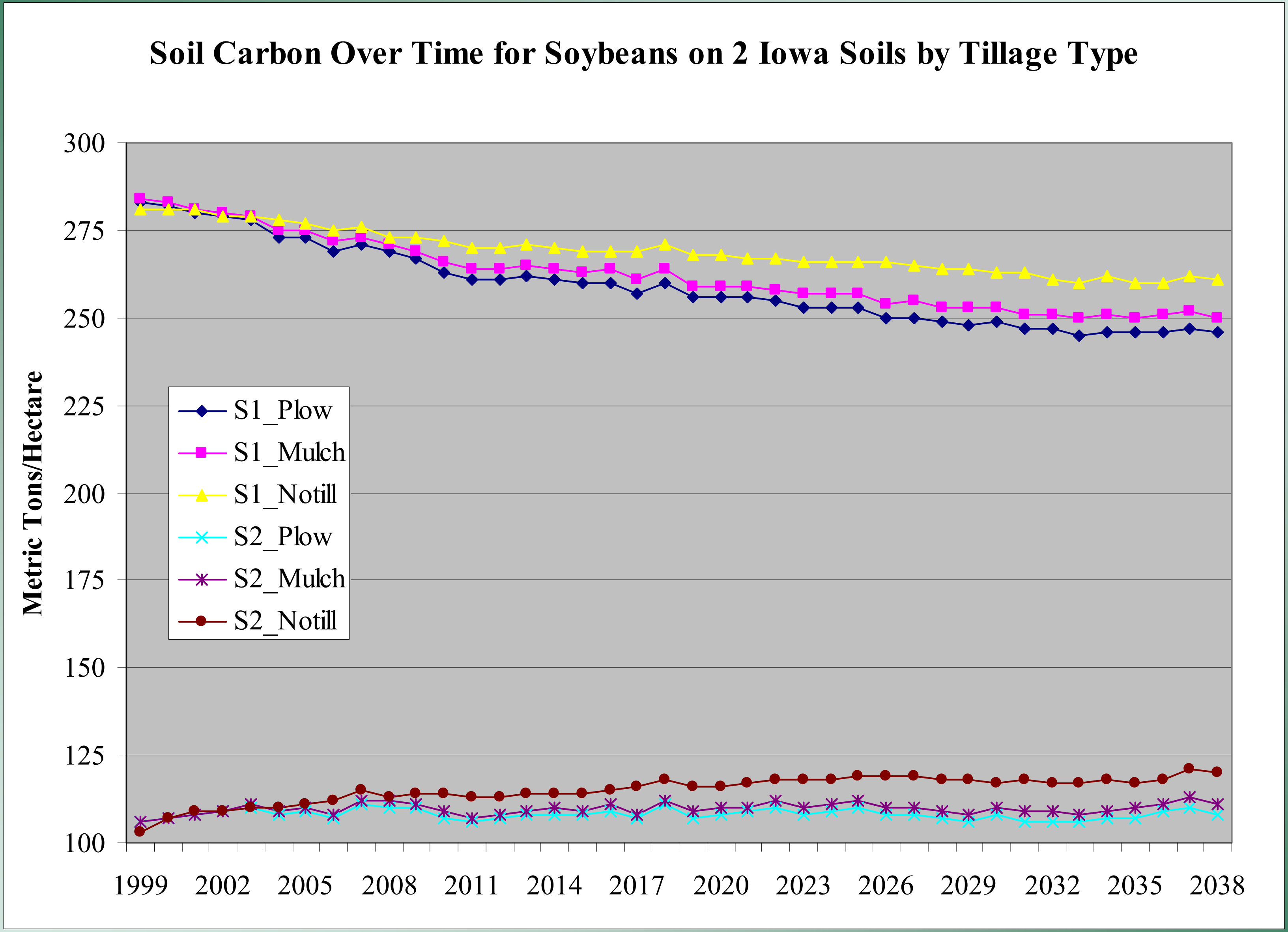




Overview of the data assembly and modeling system in EPIC




Notill C Benefit for Dryland Corn by Soil Cluster for Selected States
(Soils in each state sorted in descending order of NT benefit)
NT Benefit (g/m^2/yr) =
((NT_{30}-NT_1)- ($Till_{30}$-$Till_1$))/30
Carbon Sequestered (g/m2/yr)
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
GA
IA
MS
OH
OK
PA
SD
Truncated, one in IA at -176.7,
and one in OH at -108.9



Soil Carbon Over Time for Soybeans on 2 Iowa Soils by Tillage Type
Metric Tons/Hectare
300
275
250
225
200
175
150
125
100
1999
2002
2005
2008
2011
2014
2017
2020
2023
2026
2029
2032
2035
2038
S1_Plow
S1_Mulch
S1_Notill
S2_Plow
S2_Mulch
S2_Notill

The Century model: validation and application at the national scale

INPUT DATA

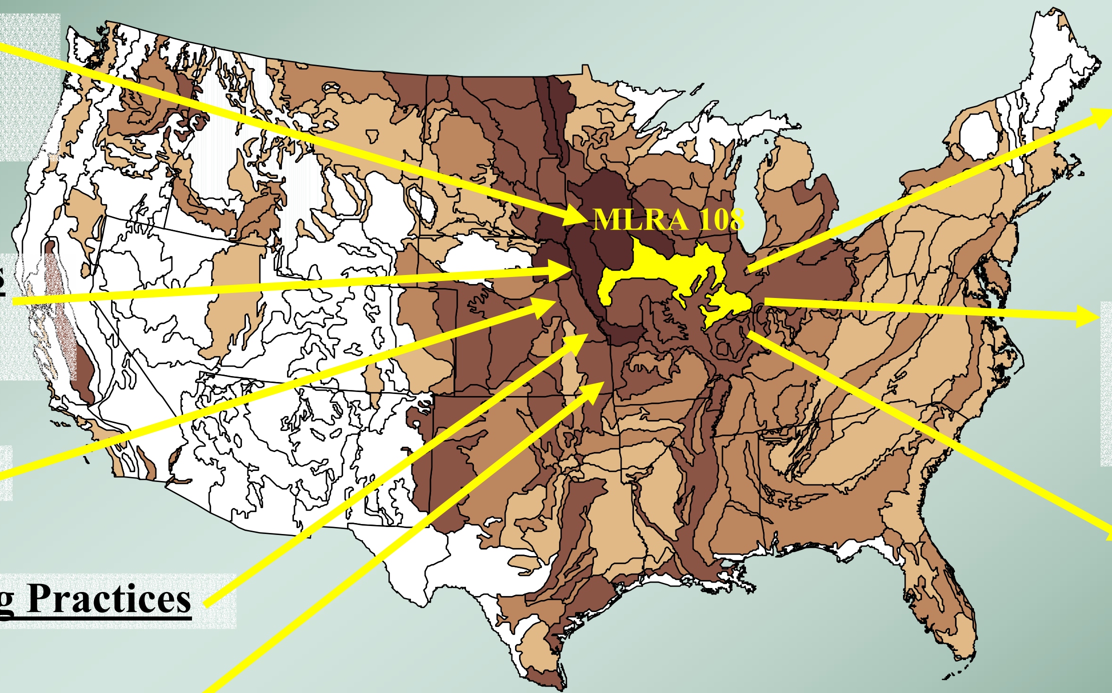
Climatic Data
- Monthly Temperature
- Monthly Precipitation

Soil Characteristics
- Texture
- Drainage

Native Vegetation

Historical Cropping Practices

Recent Cropping Practices
- Crop Rotation
- Tillage
- Fertilizer
- Irrigation



MODELED SCENARIOS

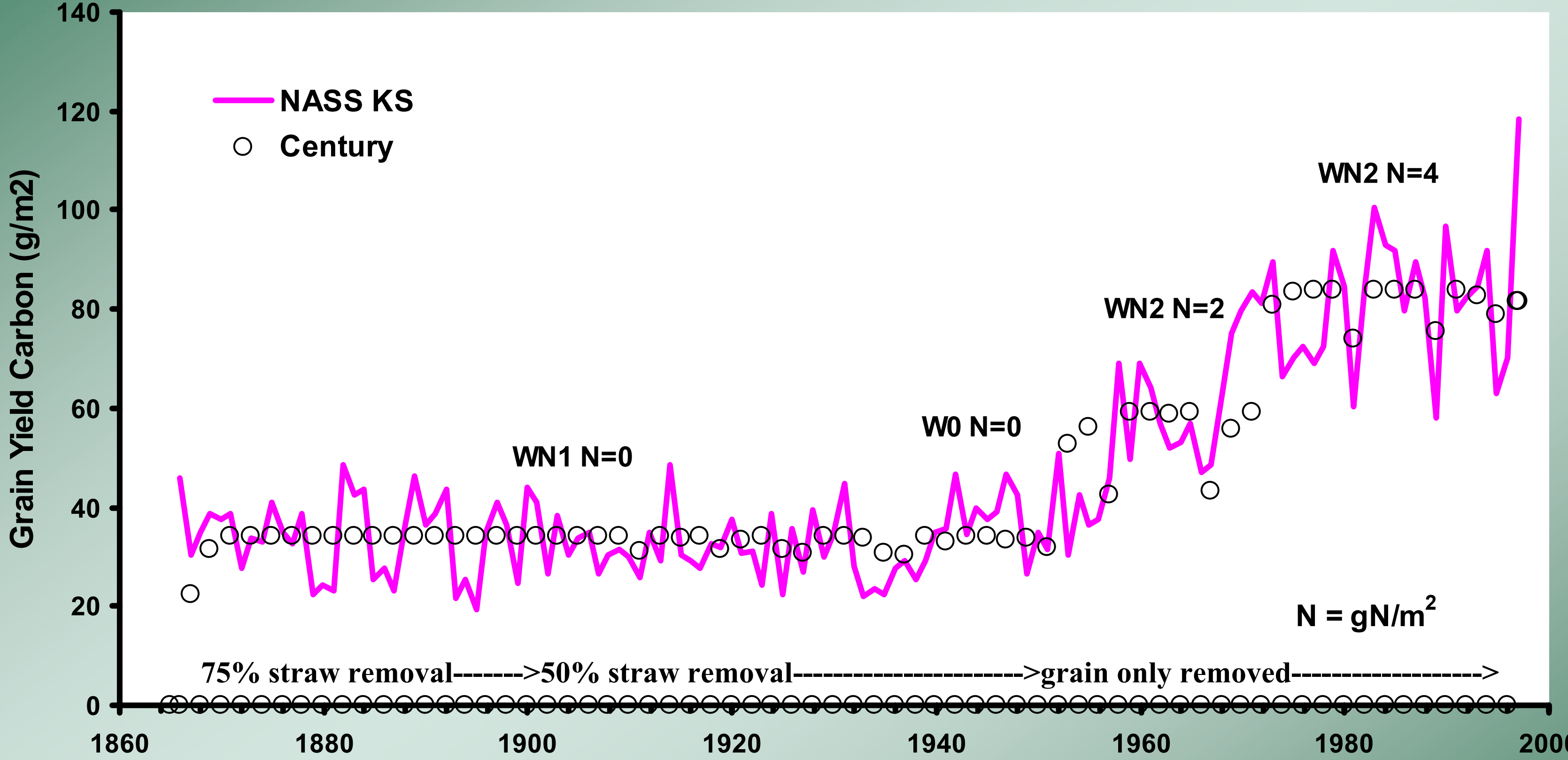
Tillage Changes
- No Till
- Reduced Tillage
- Conventional Tillage

Land Use Changes
- CRP
- Abandoned farmland
- Converted to grassland

Rotation Changes

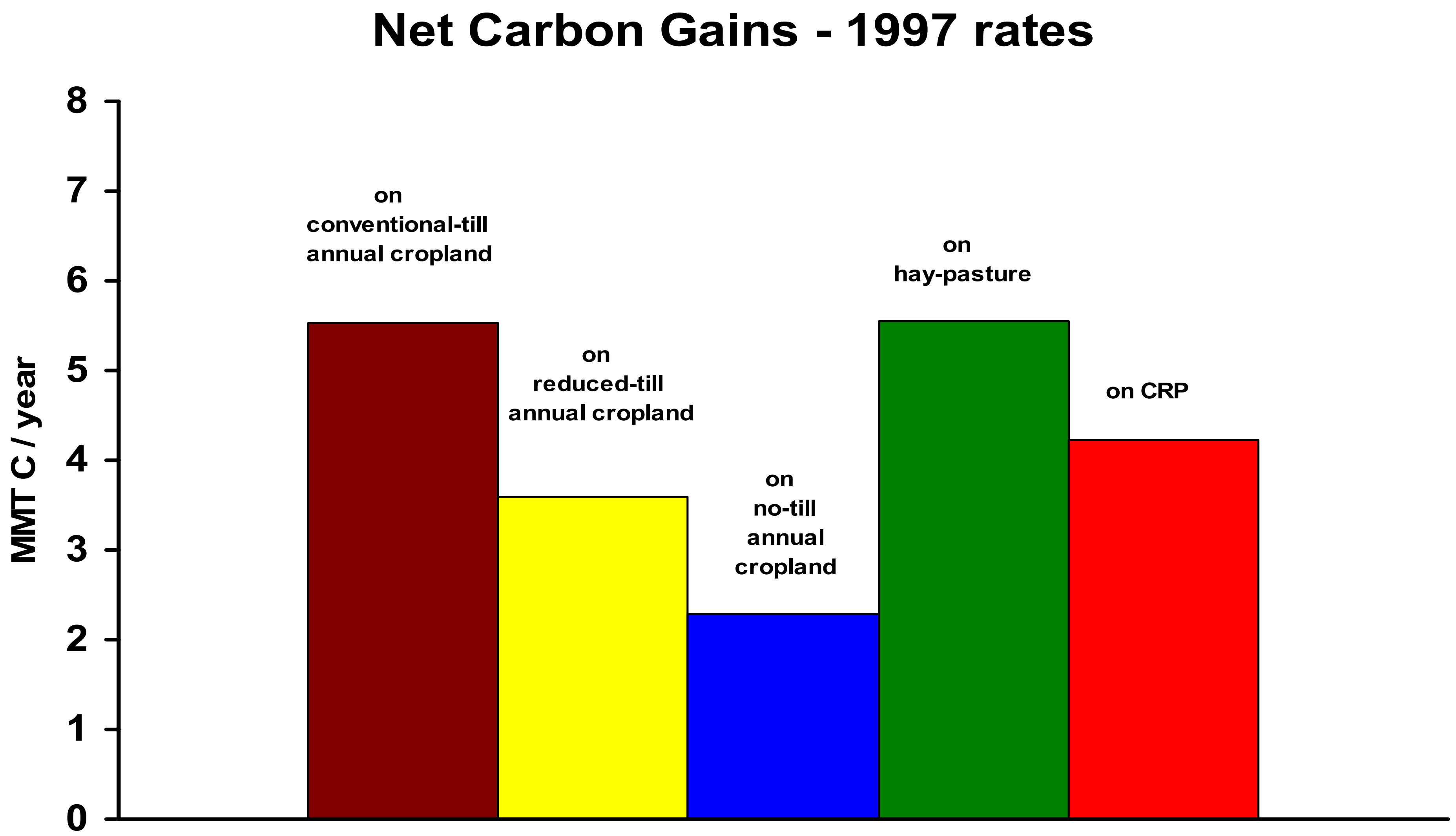
Background image shows all MLRA's that have more than 5% agricultural cropland

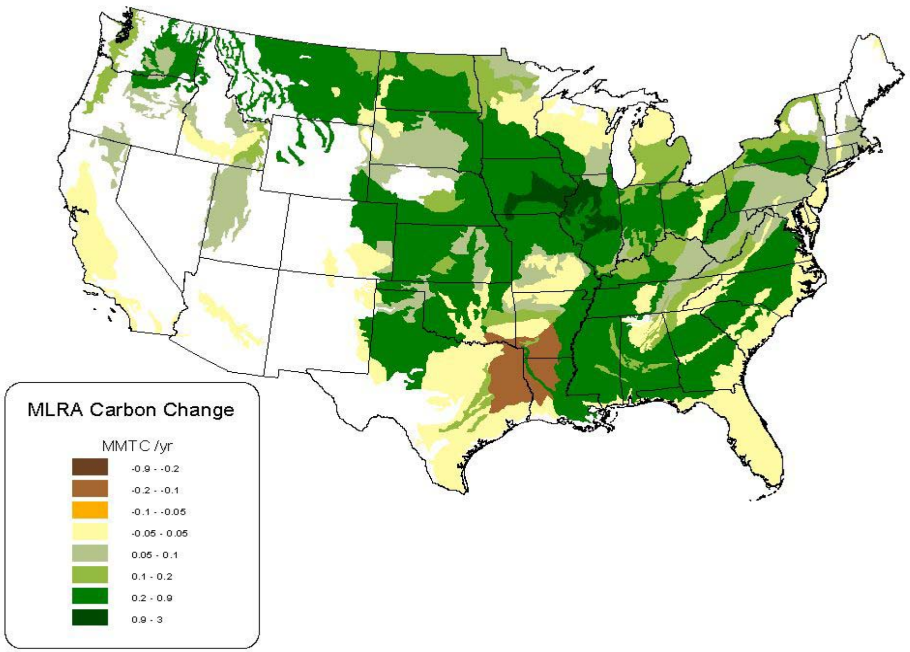
Kansas wheat-fallow test



Manhattan, KS site data used in simulation. Average monthly weather data used for 1866-1894. Measured monthly precipitaion used for 1895 onward, along with mean monthly tmax, tmin.

Aggregate Century results



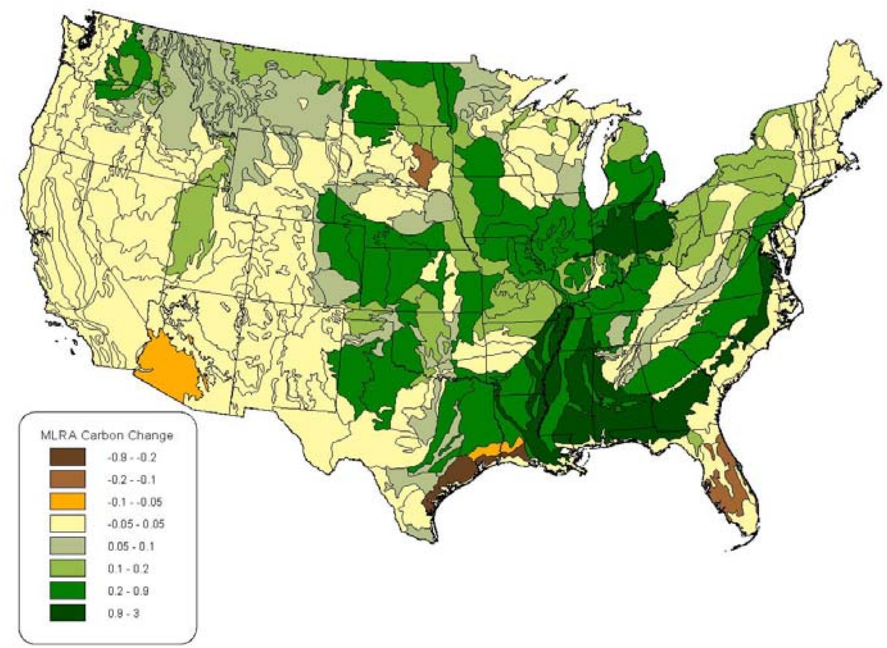


Century

21.2 MMTC yr^{-1}
on 149 Mha cropland

IPCC

18.4 MMTC yr^{-1}
on 168 Mha cropland



Summary

- Simulation modeling plays a fundamental role in predicting and understanding soil carbon sequestration at different scales of resolution
- C-STORE promises to be a useful tool to develop field-estimates of soil carbon sequestration
- Landscape modeling with APEX should help understand the role of erosion in the carbon cycle
- The use of Century and EPIC at the regional and national scales will provide independent estimates of soil carbon sequestration